Soybean Maturity Stage Estimation with Unmanned Aerial Systems

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Abstract. *Many agronomic decisions in soybean production systems revolve around crop maturity. The primary objective of this research was to evaluate the ability of UAS to determine when soybeans have reached maturity stage sufficient for harvest aid application. A producer typically applies harvest aid chemicals when he or she perceives the crop has reached a critical level of maturity (R6.5) based on a subjective assessment. A convention is to apply harvest aids when 65% of soybean pods reach a mature brown color. The use of UAS allows producers to have whole field coverage and a more objective way of determining when soybeans are mature enough to tolerate late-season harvest aid application without risking yield loss. At the small plot scale, data collection for this project consisted of UAS missions with a multi-rotor aircraft carrying a multi-spectral payload that collected reflectance in five bands (blue, green, red, near infrared, and red edge). UAS missions coincided with in-situ assessment of soybean maturity stage within research plots. Six UAS missions were conducted during the critical timing window (R5.5 to R8), approximately every 4 days. Image processing was conducted using the cloud-based application provided by the payload manufacturer, which returned a radiometrically-corrected orthomosiac image file. From the individual bands, both normalized difference vegetation index (NDVI) and variable atmospherically resistant index (VARI) were calculated using GIS software. Zonal statistics were utilized to obtain average NDVI and VARI values for each small plot for each collection date. Intuitively, NDVI and VARI decrease in tandem with maturity progression of soybean, as plants senesce and green matter dries out, withers, and turns brown. A significant high correlation was seen between decreased index values and increased maturity stage (ρ = -0.82 and -0.79, for NDVI and VARI, respectively). At this time, the study has been scaled up to production fields. A successful outcome would mean a new application for UAS using tools and data products available now at a reasonable cost, making the research outcomes immediately usable by soybean producers.*

Keywords. *Soybean, Glycine max L., unmanned aerial systems, unmanned aerial vehicles, multispectral, remote sensing, NDVI, VARI, harvest aids, small plot research, Mississippi.*

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Introduction

Many agronomic decisions in soybean production systems revolve around crop maturity. Therefore, it seems reasonable to assume rapid, objective detection of crop maturity on a field-scale is desirable for decision making. It is reasonable to consider unmanned aerial systems (UAS) as are a tool with the capability of filling this need. However, research has not yet verified this assertion. Moreover, it has not yet been determined which aspects of soybean production can benefit from application of this tool, and to what economic end.

The UAS marketplace offers a variety of affordable, easy-to-obtain, easy-to-pilot, unmanned aircraft options with high quality optics. At the same time, the US Federal Aviation Administration has lowered the hurdles to use of UAS in production agriculture through the introduction of the remote pilot certificate. This certificate allows legal use and operation of unmanned aircraft on the farm. On the engineering side, battery life (notorious for limiting potential) is improving. These improvements have made UAS more accessible, but meaningful applications of the technology are still lagging behind. From observation, most producers and consultants enjoy the novelty of "drones," but do not have the time to devote to becoming remote sensing experts. This research supposes the immediately available potential for UAS lies in (1) the ability to quickly cover more acreage, with less effort, than a field scout on foot, and (2) the objectivity inherent in computing systems (in contrast to human observer subjectivity).

The primary objective of this research was to evaluate the ability of UAS to determine when soybean (*Glycine max* L.) have reached maturity stage sufficient for harvest aid application. To increase harvest ease, soybean producers often desire to apply a late-season harvest aid chemical to desiccate the soybeans. A producer typically applies harvest aids when he or she perceives the crop has reached a critical level of maturity based on a subjective assessment. A convention is to apply harvest aids when 65% of soybean pods reach a mature brown color. The use of UAS could allow producers to have a more objective way of determining when soybeans are mature enough to tolerate late-season harvest aid application without risking yield loss. A successful outcome would mean a new application for UAS using tools and data products available now at a reasonable cost, making the research outcomes immediately usable by soybean producers.

Methods and Materials

Data collection for this project consisted of UAS missions with a multi-rotor aircraft carrying a multi-spectral payload that collected reflectance in five bands (blue, green, red, near infrared, and red edge). The aircraft was a Spyder X8 (Sky-Hero, Leuze-en-Hainaut, Belgium), and the payload was a RedEdge (Micasense, Seattle, Washington, USA). UAS missions coincided with in-situ assessment of soybean maturity stage in small research plots where various harvest aid applications were made at different maturity timings. Six UAS missions were conducted during the critical timing window (R5.5 to R8), approximately every 4 days.

Image processing was conducted using the Atlas cloud-based application (now defunct) provided by the payload manufacturer, which returned a radiometrically-corrected orthomosiac image file. From the individual bands, both normalized difference vegetation index (NDVI) and variable atmospherically resistant index (VARI) were calculated using ArcGIS (ESRI, Redlands, California, USA) software. ArcGIS was also used to extract zonal statistics. These statistics were utilized to obtain average NDVI and VARI values for each small plot.

Spearman correlations were calculated between index values and maturity stage using SAS (Cary, North Carolina, USA). Intuitively it was expected that NDVI and VARI would decrease in tandem with maturity progression of soybean, as plants senesced and green matter dried out, withered, and turned brown.

Results and Discussion

A significant high correlation was seen between decreased index values and increased maturity stage ($\rho = -0.82$ and -0.79, for NDVI and VARI, respectively). A visible shift was seen in NDVI and VARI values as soybean maturity progressed (Figure 1).

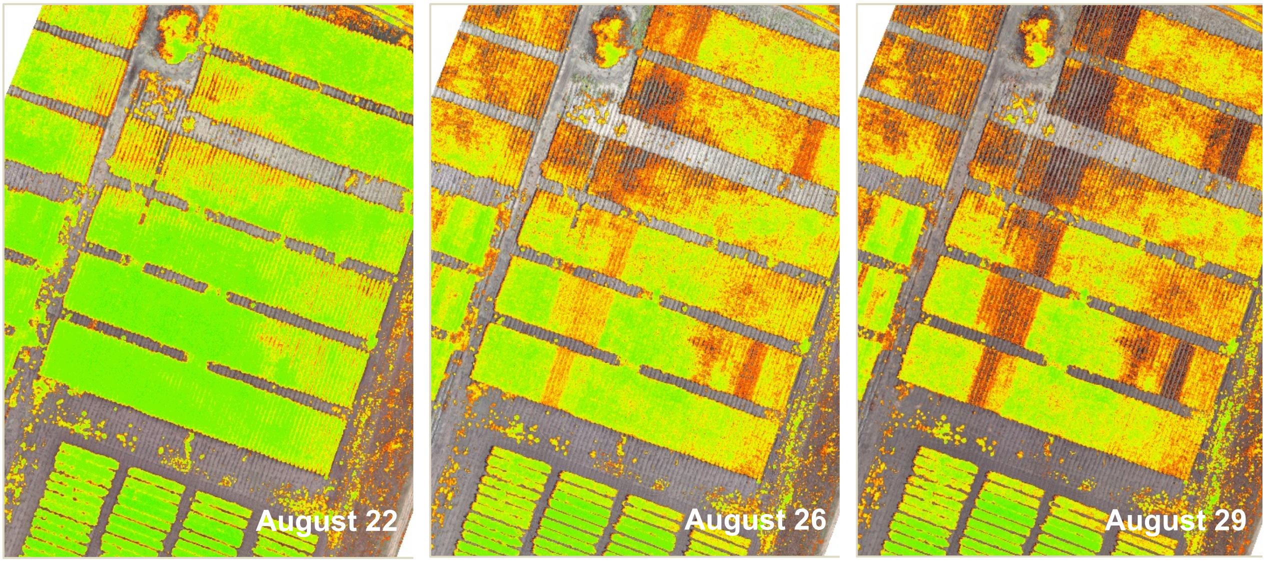

Figure 1. Time series of Normalized Difference Vegetation Index (NDVI) values in response to harvest aid application and soybean maturity progression. Brighter green colors (lighter areas in grayscale) correspond to more green vegetation present in the field. Orange and red values (darker areas in grayscale) correspond to less green vegetation present in the field. Areas with no color indicated limited green vegetation present.

Operationally speaking, the use of an index as the measuring tool is desirable because NDVI and VARI are easy for producers and/or consultants to obtain. Most cloud and desktop processing options provide one or both of these indices automatically. Additionally, indices reduce the influence of extraneous variability inherent in time series of images. If maturity estimation could be linked to either of these indices, implementation could be nearly immediate. A challenge that remains is determining what level of NDVI or VARI corresponds to what is perceived by a scout as “65% brown pods” as this varies between individual scouts.

The study was conducted using research plots where a separate study on efficacy and timing of various harvest aids was performed. Accordingly, behavior of soybean between plots may have been impacted by variability due to the treatment assigned to the plot. Potentially the relationship between maturity and index value is a function of the rate of change, rather than an absolute number. A trend such as this would have been subject to external influence of assigned treatment. This trend would not be present within a production field, as the producer would apply a single chemical. Therefore, the response as a change function has not been investigated within this data. However, it is the subject of future research in production fields.

Conclusion

The small plot trial showed sufficient evidence to support scaling up the research to production field levels. The potential exists, but due to the direct effect of harvest aid application timing on yield, more study is warranted. This effort is underway at this time.

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